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"Use of MAGSAT anomaly data for crustal structure and mineral resources in the U.S. Midcontinent"

from

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Quarterly Report

Our activity is continuing on the interpretation of the processed Magsat data and maps. Two graduate students are engaged in identifying long-wavelength "regional" effects that might be associated with varying crustal thickness or Curie-temperature depths, and trying to associate the remaining "residual" anomalies with causative geology and structure.

An interesting source of correlative data for study of Magsat anomalies over the U.S. will be the (color) digital Bouguer gravity maps, as filtered at 250 and 1000 km wavelengths, recently produced by the U.S.G.S. (Hildenbrand et al, 1982).

Enclosed is an abstract submitted for the "Magsat results" session planned for the Annual Meeting of the Society of Exploration Geophysicists (Dallas, October). This is a large group of geophysical data users who should be interested in how good-resolution satellite data might be integrated into a reconnaissance exploration program for petroleum and minerals.

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Abstract for: Annual Meeting, Society of Exploration Geophysicists
("MAGSAT results" session)
October 17-21, 1982; Dallas, Texas

To: Edwin Neitzel, Technical Program Chairman
and for transmission to William Hinze, Session coordinator

Use of MAGSAT satellite magnetic anomaly data to interpret crustal character and resource potential of the U.S. mid-continent

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Summary

The assessment of future resources of petroleum, minerals, and geothermal energy, is best served by an exploration strategy that combines geophysical exploration with geologic interpretation of the structure, composition, and thermal and tectonic development of the Earth's upper crust. A promising tool for reconnaissance exploration of the crust and its energy and resource potential is the use of satellite sensing and measurements. NASA's MAGSAT satellite measured, in 1980, the Earth's long-wavelength magnetic field anomalies arising from major crustal sources. Acquired at altitudes of 350-560 km, this data provides global coverage with resolution not previously achieved by satellite sensing. MAGSAT anomalies have a magnitude range up to 26 gammas, and a magnetic-source resolution of about 150-200 km.

The satellite data, used in conjunction with correlative geophysical and geological data such as aeromagnetics, gravity, LANDSAT imagery, and nearsurface geology, can lead to better understanding of major

deep-seated geologic structure and conditions, and the associated potential for the localization of energy and mineral resources. With the central U.S. as a study area, we have been investigating the use and applicability of the satellite magnetic data in interpreting the midcontinent's crustal structure and composition. The anomaly data set has been derived by processing the original satellite data, reducing to a $1^{o}x1^{o}$ latitude/longitude grid at a common altitude datum of 400 km, applying wavelength filtering, and then reducing the data "to the pole" to aid in interpretation. The major anomalous features are a magnetic high over Kentucky, a high over northern Texas and extending to the northeast towards Lake Michigan, and magnetic lows over the Mississippi embayment, and South Dakota. These features are interpreted in terms of variation in crustal thickness, depth of Curie-temperature isotherm, and petrologic variation between different geologic provinces. Supporting information is provided by gravity anomalies, and crustal thickness as determined from regional seismic data.

ABSTRACT

Exploration for future supplies of energy fuels (oil, gas), mineral resources, and geothermal energy, will be best pursued by combining geophysical prospecting with geologic interpretation of the structure, petrologic character, tectonic history, and thermal and chemical condition of the Earth's crust. A promising tool for aiding in reconnaissance exploration of energy and resource provinces, and potential localization of economic objectives, is the use of satellite sensing and measurements.

NASA's MAGSAT satellite measured, in 1980, the Earth's magnetic field anomalies arising from major crustal sources. This was the first satellite to measure component-field (i.e. X, Y, Z) data to yield relatively low-altitude global magnetic anomaly maps. These maps have a resolution not previously achieved by satellite magnetic-field surveying. The satellite operated at altitudes of 350-560 km, mapped anomalies having a magnitude range up to 26 gammas (nanoteslas), and yielded a magnetic source resolution of about 150-200 km.

The satellite magnetic data, and resulting maps, constitute a new aid for interpreting the crust of the Earth and as a reconnaissance component in a geophysical exploration strategy. They can be integrated with

correlative geophysical and geological data sets such as aeromagnetics, gravity coverage, LANDSAT remote sensing imagery, and nearsurface geology. This can lead to a better understanding of crustal geologic structure and composition, and the associated energy and mineral resource potential. The long-wavelength magnetic anomalies measured at satellite elevations are expected to reflect differences in crustal thickness, the petrologic character and properties of major geologic provinces, and variations in geothermal gradient and thus the depth of the Curie-temperature isotherm.

With the central U.S. as a study area, we have been investigating the applicability of the satellite magnetic data in interpreting the Midcontinent's crustal geologic structure and composition. NASA/Goddard Space Flight Center has provided MAGSAT data as measured along the satellite tracks, with some preliminary corrections applied. We have then done computer processing and analysis of the data set, with steps including: i) removal of spurious data points, arising from the data acquisition process rather than from terrestrial sources; ii) statistical smoothing, comparison, and correlation of individual data tracks, to reduce the effect of geomagnetic temporal and transient disturbances; iii) reduction of data by weighted averaging to a grid with $1^{o}x1^{o}$ latitude/longitude spacing, with altitudes interpolated and weighted to a common datum elevation of 400 km (from the orbit range of 350-560 km); iv) wavelength filtering, to remove (or retain) anomaly features of desired wavelengths; and v) reduction of the anomaly map "to the magnetic pole" to compensate for variation of magnetic inclination with latitude and aid in interpreting the anomalies with respect to causative crustal features.

Figure 1 shows the MAGSAT anomaly map we have extracted from the data, for the central U.S. Here, as for subsequent figures, it is for magnitude (i.e. scalar) data, as calculated from the X, Y, and Z-component vector data as measured by the satellite. The actual area of processed data is about 50% larger than shown, and this beltway around the study area was used to prevent "edge effects" in the processing to follow.

Figure 2 shows the previous map, now filtered with a low-cut wavelength filter which removes wavelengths less than about 400 km. This map has similarities to maps of some previous satellite studies over the U.S., but is more detailed and revealing because of i) the care

taken in removing bad data points and tracks, and comparing profiles to optimize data reliability, and ii) treating the data on a finer $1^{o}x1^{o}$ grid rather than the customary but coarser $2^{o}x2^{o}$ grid spacing often used for global-scale maps. For comparison, Figure 3 shows the MAGSAT anomaly map as derived by NASA (March 1981) from a preliminary global data set. There is less detail in the latter, and it is a prime purpose of our study to assess, for prospective resource exploration and crustal interpreation, how far the satellite magnetics resolution can be extended by data processing and analysis.

Figure 4 shows the data of Figure 2, now reduced to the magnetic pole. The alteration is not dramatic, because of the relatively high magnetic latitude (about 45-65^{o}N.) of the study area with respect to the north magnetic pole. The major magnetic highs have been shifted north--the north Texas one up to the Oklahoma border, and the Tennessee one up into Kentucky.

Several major anomalous features are observed on the processed scalar magnitude map (Black, 1981) of Figure 4. They are: i) a bullseye magnetic high over Kentucky, as noted on previous POGO satellite data and interpreted by others as due to a mafic basement rock complex and intrusion in the lower crust, ii) an arcuate magnetic high extending from its maximum over northern Texas up to the northeast and the Lake Michigan area, probably originating from a zone of greater crustal thickness developed in late Precambrian time, iii) a magnetic low over the Mississippi embayment/rift, as noted by others and having an origin associated with a combination of crustal thinning accompanying failed (paleo)rifting, petrologic character of the lower crust, and elevated Curie-temperature isotherm, and iv) a magnetic low over South Dakota.

Supporting correlative information for this study of satellite magnetic anomaly data includes the distribution of basement rock provinces, gravity anomaly data, and crustal thickness as determined from regional seismic data. For example, in the midcontinent region the areas of thicker crust (i.e. thickness over 45 km) are those with the magnetic highs on the satellite map--north Texas/Oklahoma, and Kentucky/Tennessee.

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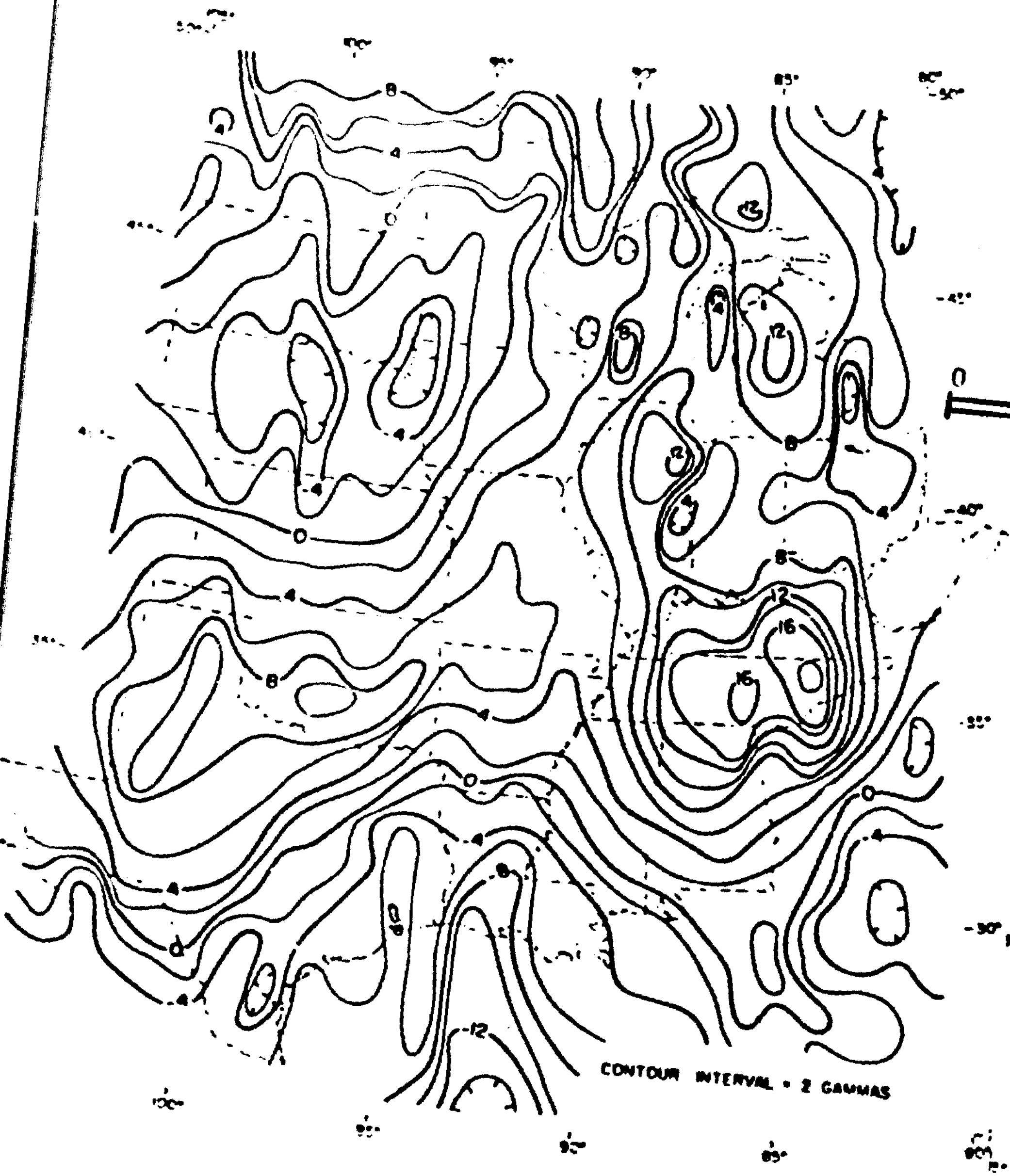

FIGURE 1. $1^{o} \times 1^{o}$ weighted-averaged Magsat scalar (magnitude) data. for the U.S. midcontinent. Albers equal-area projection. Plot by Black (1981).

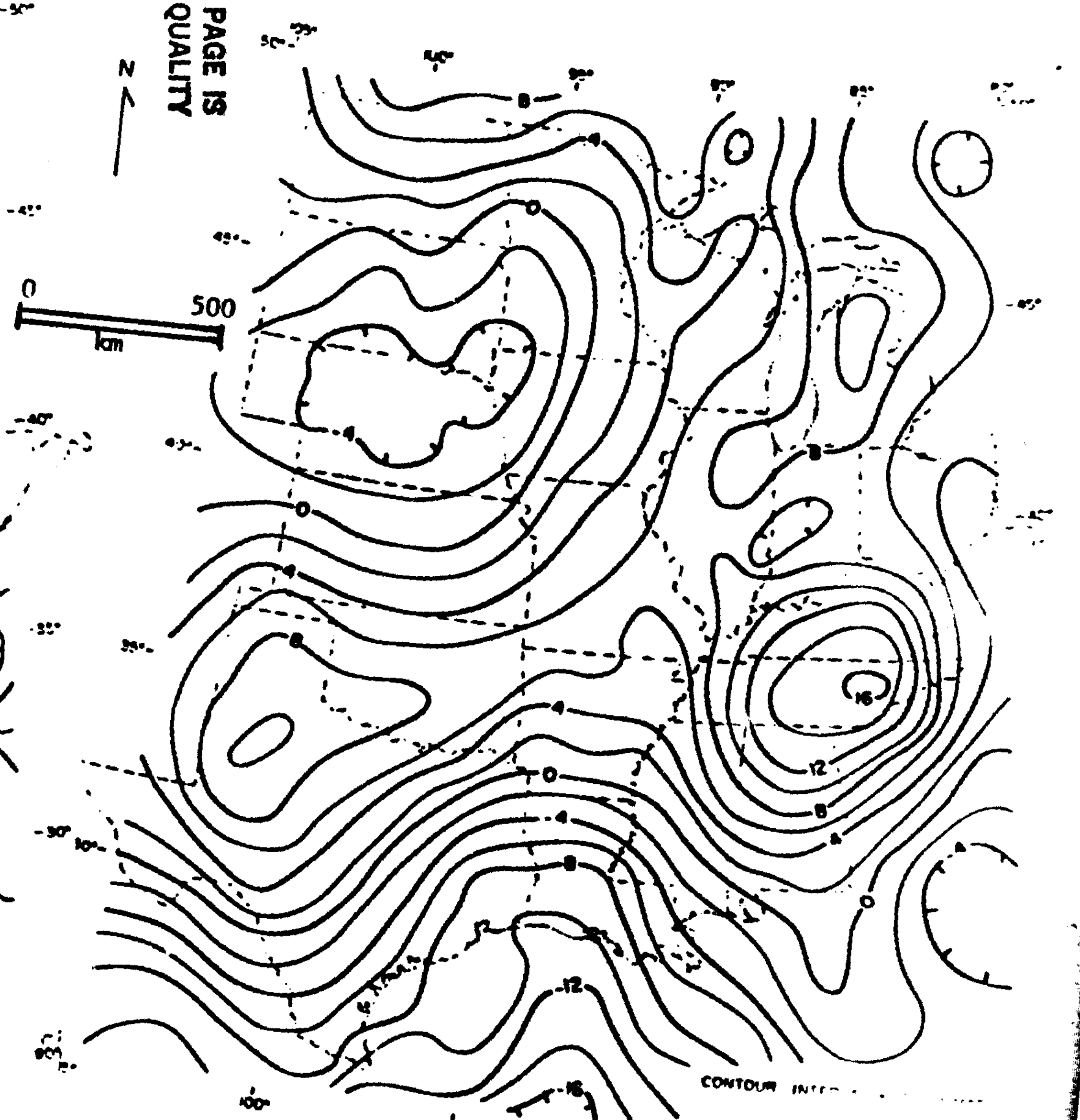

FIGURE 2. Low-cut (400 km) wavelength-filtered scalar data of Fig. 1

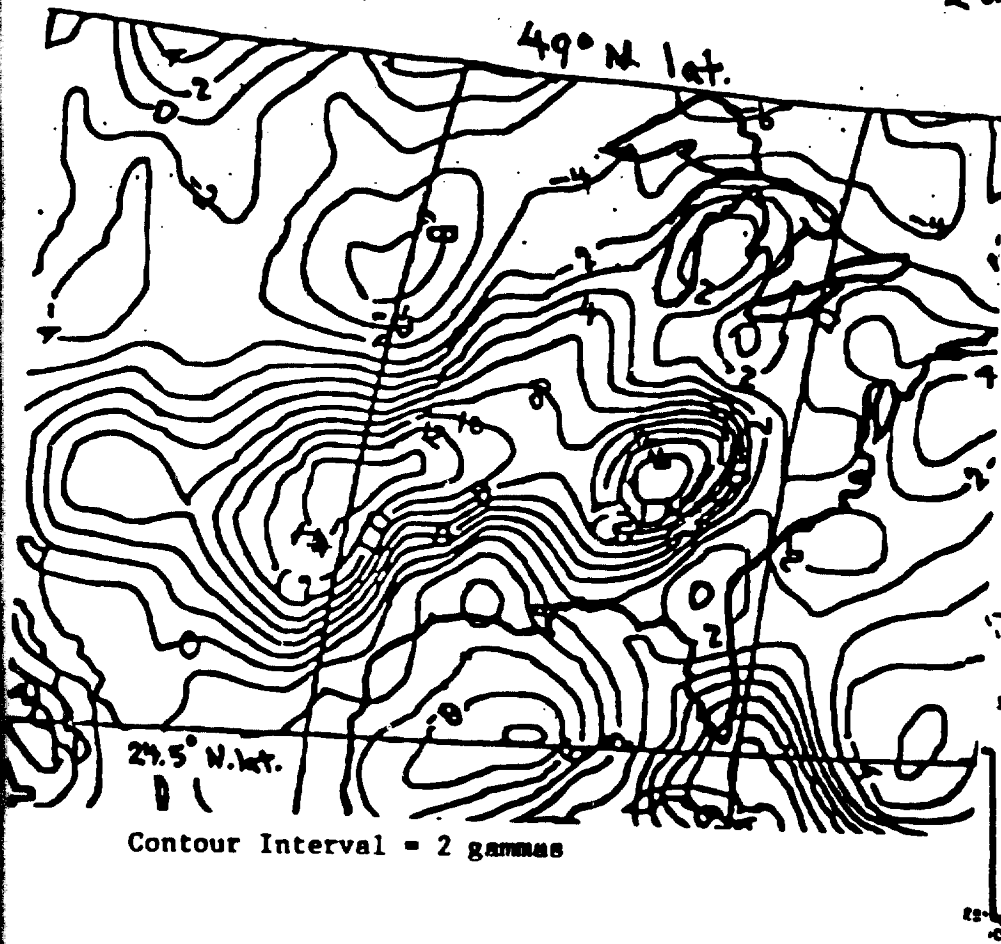

FIGURE 3. NASA's preliminary Magsat scalar anomaly map. Data from below 400 km, on $2^{o}x2^{o}$ blocks.

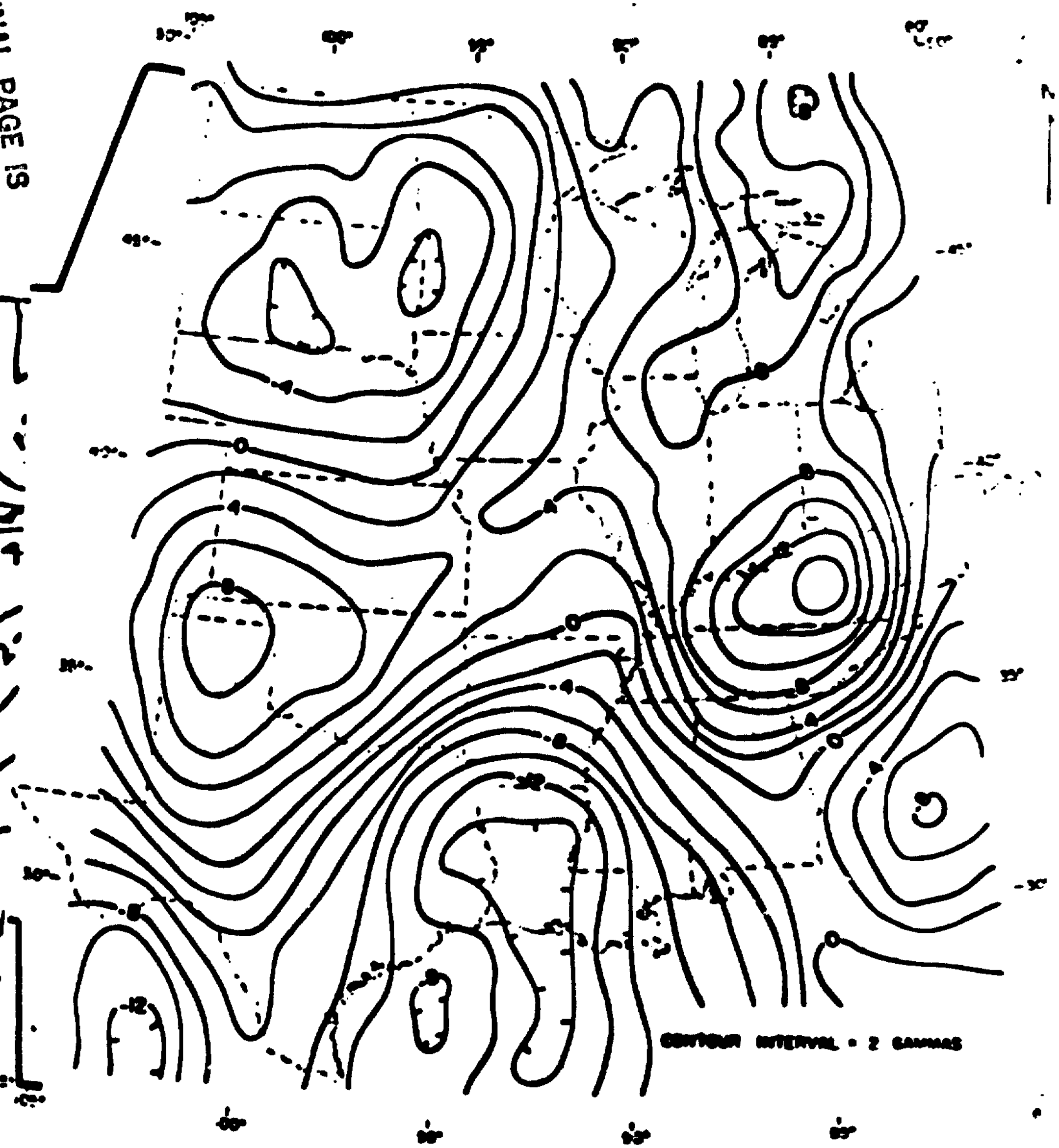

FIGURE 4. $1^{o}x1^{o}$ scalar data at 400 km altitude, high-pass filtered and reduced to the magnetic pole.